

OPTIMALLY SCHEDULING OF CLOSE-DOWN PROCESS FOR SINGLE-ARM CLUSTER TOOLS WITH WAFER RESIDENCY TIME CONSTRAINTS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 62/221,027, filed on Sep. 20, 2015, which is incorporated by reference herein in its entirety.

FIELD OF THE INVENTION

[0002] The present invention relates to a method for scheduling a process for single-arm cluster tools. More particularly, the present invention relates to a method for scheduling close-down process for single-arm cluster tools with wafer residency time constraints.

BACKGROUND

[0003] The following references are cited in the specification. Disclosures of these references are incorporated herein by reference in their entirety.

LIST OF REFERENCES

[0004] A. Caloini, G. A. Magnani, M. Pezz e, "A technique for designing robotic control systems based on Petri nets," *IEEE Transactions on Control Systems and Technology*, vol. 6, no. 1, pp. 72-87, 1998.

[0005] W. K. V. Chan, J. Yi, and S. Ding, "Optimal scheduling of multicluster tools with constant robot moving times, part I: two-cluster analysis," *IEEE Transactions on Automation Science and Engineering*, vol.8 no. 1, pp. 5-16, January 2011.

[0006] S. Ding, J. Yi, and M. Zhang, "Scheduling multicluster tools: An integrated event graph and network model approach," *IEEE Transactions on Semiconductor Manufacturing*, vol. 19, no. 3, pp. 339-351, August 2006.

[0007] L. Ferrarini and L. Piroddi, "Modeling and control of fluid transportation operations in production plants with Petri nets," *IEEE Transactions on Control Systems and Technology*, vol. 16, no. 5, pp. 1090-1098, 2008.

[0008] D. Liu, Z. W. Li, and M. C. Zhou, "Hybrid Liveness-Enforcing Policy for Generalized Petri Net Models of Flexible Manufacturing Systems," *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, 43(1), pp. 85-97, January 2013.

[0009] C. Jung and T.-E. Lee, "An efficient mixed integer programming model based on timed Petri nets for diverse complex cluster tool scheduling problems," *IEEE Transactions on Semiconductor Manufacturing*, vol. 25, no. 2, pp. 186-199, 2012.

[0010] T. K. Kim, C. Jung and T. E. Lee, "Scheduling start-up and close-down periods of dual-armed cluster tools with wafer delay regulation" *International Journal of Production Research*, vol. 50, no. 10, pp. 2785-2795, May 2012.

[0011] D. K. Kim, T. E. Lee, and H. J. Kim, "Optimal scheduling of transient cycles for single-armed cluster tools," in Proceedings of the 2013 *IEEE International Conference on Automation Science and Engineering*, Madison, Wis., USA, August 2013a.

[0012] H. J. Kim, J. H. Lee, C. Jung, and T. E. Lee, "Scheduling cluster tools with ready time constraints for consecutive small lots," *IEEE Transactions on Automation Science and Engineering*, vol. 10, no. 1, pp. 145-159, January 2013b.

[0013] H. J. Kim, J. H. Lee, and T. E. Lee, "Noncyclic scheduling of cluster tools with a branch and bound algorithm," *IEEE Transactions on Automation Science and Engineering*, DOI: 10.1109/TASE.2013.2293552, 2013c.

[0014] J.-H. Kim, T.-E. Lee, H.-Y. Lee, and D.-B. Park, "Scheduling analysis of timed-constrained dual-armed cluster tools," *IEEE Transactions on Semiconductor Manufacturing*, vol. 16, no. 3, 521-534, 2003.

[0015] J. H. Lee, H. J. Kim, and T. E. Lee, "Scheduling transient periods of dual-armed cluster tools," in Proceedings of the 2012 *IEEE International Conference on Mechatronics and Automation*, Chengdu, China, pp. 1569-1574, August 2012.

[0016] J. H. Lee, H. J. Kim, and T. E. Lee, "Scheduling lot switching operations for cluster tools," *IEEE Transactions on Semiconductor Manufacturing*, vol. 26, no. 4, pp. 592-601, 2013.

[0017] J. H. Lee, H. J. Kim, and T. E. Lee, "Scheduling cluster tools for concurrent processing of two wafer types," *IEEE Transactions on Automation Science Engineering*, vol. 11, no. 2, pp. 525-536, 2014.

[0018] T.-E. Lee, H.-Y. Lee, and Y.-H. Shin, "Workload balancing and scheduling of a single-armed cluster tool," in *Proceedings of the 5th APIEMS Conference*, Gold Coast, Australia, 1-15, 2004.

[0019] T.-E. Lee and S.-H. Park, "An extended event graph with negative places and tokens for timed window constraints," *IEEE Transactions on Automation Science and Engineering*, vol. 2, no. 4, 319-332, 2005.

[0020] D.-Y. Liao, M. D. Jeng, and M. C. Zhou, "Petri net modeling and Lagrangian relaxation approach to vehicle scheduling in 300 mm semiconductor manufacturing," in *Proc. 2004 IEEE International Conference on Robotics and Automation*, New Orleans, La., 2004, pp. 5301-5306.

[0021] M.-J. Lopez and S.-C. Wood, "Systems of multiple cluster tools—configuration, reliability, and performance," *IEEE Transactions on Semiconductor Manufacturing*, vol. 16, no. 2, 170-178, 2003.

[0022] T. L. Perkinson, P. K. Maclarty, R. S. Gyurcsik, and R. K. Cavin, III, "Single-wafer cluster tools performance: An analysis of throughput," *IEEE Transactions on Semiconductor Manufacturing*, vol. 7, no. 2, pp. 369-373, May 1994.

[0023] T. L. Perkinson, R. S. Gyurcsik, and P. K. Maclarty, "Single-wafer cluster tool performance: An analysis of effects of redundant chambers and revisitation sequences on throughput," *IEEE Transactions on Semiconductor Manufacturing*, vol. 9, no. 2, pp. 384-400, May 1996.

[0024] Y. Qiao, N. Q. Wu, and M. C. Zhou, "Petri net modeling and wafer sojourn time analysis of single-arm cluster tools with residency time constraints and activity time variation," *IEEE Transactions on Semiconductor manufacturing*, vol. 25, no. 3, 432-446, 2012a.

[0025] Y. Qiao, N. Q. Wu, and M. C. Zhou, "Real-time scheduling of single-arm cluster tools subject to residency time constraints and bounded activity time variation,"